NAVI: A Problem Solving Environment (PSE) for NIRS Data Analysis

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OVERVIEW

What is NAVI?

Growing interest in NIRS imaging is generating an increasing demand for an integrated computing environment capable of exploring the richness and complexity of spatiotemporal measures of blood delivery to tissue. As with other complex systems, key to their study is a PSE that allows for the description, discovery and analysis of relevant phenomenology in ways that retain computational efficiency and facilitate file management. NAVI, (**N**ear-infrared **A**nalysis, **V**isualization and **I**maging), is a rich constellation of instrument performance monitoring, filtering, image formation, feature extraction, visualization, statistical analysis, and file and database management tools for the examination of functional NIRS data.

NAVI utilizes the MATLAB run-time component and is distributed as a stand alone program for Windows® or Linux. NAVI offers point-and-click navigation and visualization of data within a flexible file management system that employs wizards to facilitate group data loading, batch processing, automated file system creation, and recording of parameter settings used in data processing. Image visualization is available through a variety of styles and makes generous use of montage formats for the overlay of multi-feature information.

By optimizing the balance between computational effort and computer memory together with use of fast algorithms NAVI enables the analysis and visualization of large-scale data sets. In addition, NAVI's image conversion function allows the export of NAVI-generated images into standard image formats for use with other software packages such as SPM, Medx, AFNI and GID.

Figure 1 shows a screenshot of the NAVI home screen comprising three principal portals: Image Generation, Data/Image Display and Data/Image Analysis. Each of key features included in the software package is discussed in the next section.

MAIN FEATURES

File Management and Electronic Ledger

Two key elements of the NAVI design are the incorporation of an automated file generation system and its use of electronic ledger. Having loaded raw data from the scanner once, thereafter all file generation and management is achieved through a single file that is integrated with a background data base. Data loading for viewing and analysis is achieved efficiently and without the need to navigate using the typical approach of an ever expanding, user-generated file tree structure.

The electronic ledger keeps track of all facets of data generation including instrument scanning parameters, FEM mesh details, and selected parameters used for data filtering, editing, feature extraction, etc. In short, all of the particulars needed to uniquely define the operations used for all steps of data processing are stored automatically in an organized and easily accessible format.

Image Generator

The Image Generation portal allows for viewing, editing, filtering, and normalization of the raw wavelength time-series and computation of hemoglobin states (oxy-, deoxy-, total-Hb, HbO2 saturation). It also provides for specification of different linear-reconstruction methods (truncated SVD, LU-decomposition) for recovery of wavelength dependent absorption and scattering coefficients/Hb states, access to stored FEM mesh libraries, toolboxes for generating a FEM meshes from anatomical priors or other user
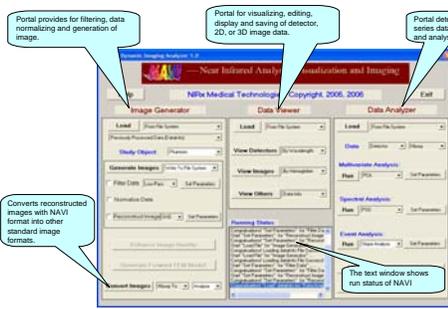
Figure 1. Home screen of NAVI - a problem solving environment for NIRS imaging.
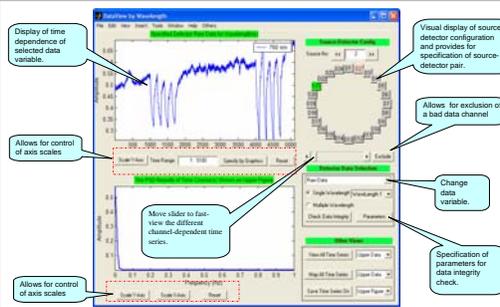
Figure 2. Viewing and editing detector data set using Data Viewer
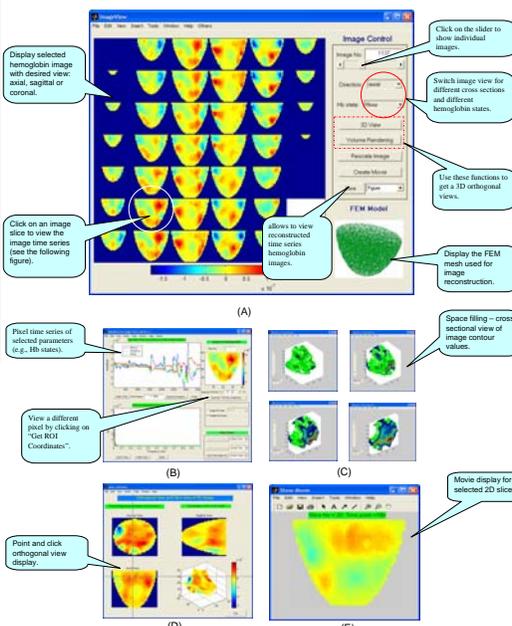
Figure 3. Viewing image time series using Data Viewer: (a) individual image frame with an axial section view; (b) pixel time course view associated with selected slice; © individual image frame with volume rendering views; (d) individual image frame with a orthogonal composition view of intersecting planes ; (e) movie display for a specified slice.

definable media, a diffusion-based DC forward solver for computation of surface intensities and Jacobian operators as well as access to an image enhancement scheme described in other abstracts at this meeting.

Data Viewer

The data viewing portal provides for a broad range of viewing options, editing, and storage that can be applied to detector channel and 2D, 3D, volume rendered image data. Included are options for generation of movies, display of selected or complete channel/pixel time series, montage formats, and display of image data in a axial, coronal or sagittal view (see Figures 2 and 3).

Data Analyzer

The data analysis portal provides feature extraction capabilities for blind or model driven signal separation (Principal Component Analysis, Molgeday-Schuster Analysis, Independent Component Analysis, General Linear Model), spectral analysis (Power Spectral Density, Cross Spectral Density, Coherence, Time Correlation, Wavelet, others), and event analysis (slope, time-delay, Area Under Curve). Exemplary screens shots employing the GLM method are shown in Figure 4.

Under development are toolboxes for uni- and multi-variate analysis applied to allow for generation of statistical parametric maps. Also being developed is an integrated, web-accessible and secure SQL open source data base, originally developed by investigators at McGill University (OSCAR), to allow for data sharing between investigative teams.

Figure 5 shows results generated by using AFNI with imported NIRS time series images that were derived from a DYNOT-based experimental data for study verbal working memory in health adults.

CONCLUSIONS

We have developed a versatile problem solving environment that provides for the efficient and bulk processing of large scale NIRS data files. Available capabilities include: image generation, image enhancement, feature extraction and statistical parametric mapping, multiple display and data editing capabilities, automated file generation and an electronic ledger.

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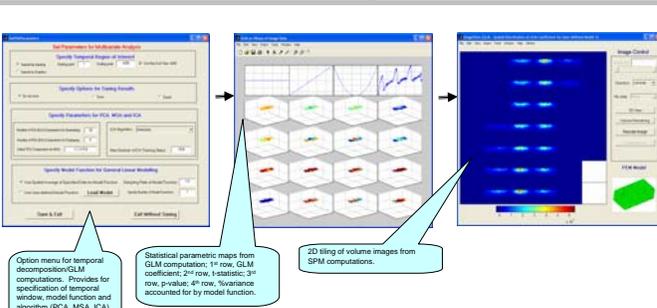
Figure 4. Screen shots of process used for GLM and Slope Analysis in Data Analyzer:
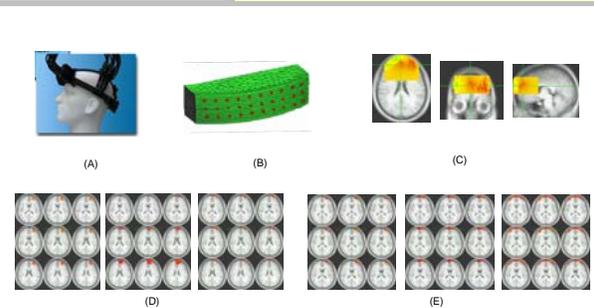
Figure 5. Results derived from AFNI, with imported NAVI-based NIRS image for verbal working memory: (A) Image head used for data collection; (B) FEM model used for imaging reconstruction; (C) NIRS images fitting with a brain template; (D) oxy-Hb increase with task loading increase for 1-0 back condition; (E) oxy-Hb increase with task loading increase for 3-2 back condition.